Original Research

Acute changes in hamstring flexibility: PNF versus static stretch in senior athletes

J. Brent Feland, J. W. Myrer and R. M. Merrill

Few studies have reported on the amount of acute changes in flexibility of the hamstrings resulting from stretching prior to activity, and no studies of this nature have focused on an elderly population. Methods: Ninety-seven subjects (mean age = 65 years, range 55–79 years) participating in the World Senior Games were randomly selected for participation in this study. Subjects were randomly assigned to either a control group (no stretching), or one of two treatment groups (contract-relax proprioceptive neuromuscular facilitation stretch [CRPNF], or a static stretch). Hamstring flexibility was measured with a Penny and Giles goniometer prior to and after one repetition of stretching lasting 32 seconds. Analysis: Differences in flexibility scores from pretest to posttest for control and two treatment groups were assessed using the Wilcoxon signed-ranks test. Pair-wise comparisons in median differences between groups were assessed using rank analysis of covariance and the Mantel-Haenszel statistic. Results: Flexibility scores for participants in each of the control and treatment groups significantly increased from pretest to posttest. However, the increase was much greater for those in the two treatment groups, with median differences of 1 degree in the control group, 5 degrees in the CRPNF group, and 4 degrees in the static group. Both gender and age influenced the median difference between CRPNF and static groups. Specifically, the median difference was significantly greater in the CRPNF versus the static group for men but not women. Similarly, the median difference was significantly greater in the CRPNF versus the static group for participants younger than age 65 but not aged 65 years or older. Conclusion: One repetition (32 seconds) of stretching provides an acute increase in flexibility of the hamstrings. CRPNF and static stretches significantly improve flexibility. For men and participants less than 65 years of age, CRPNF stretch appears more beneficial than static stretch. The benefits in flexibility between CRPNF and static stretches are similar for women and participant ages 65 years and older. © 2001 Harcourt Publishers Ltd

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Introduction

Many investigators have studied methods of improving hamstring flexibility. However, controversy remains concerning the method, intensity, duration and frequency that is the most beneficial or yields the greatest results.

Stretching has long been touted as an important adjunct to a physical fitness program, and a variety of stretching techniques exist to enhance flexibility and range of motion (ROM). While many studies have observed differences between using a static stretch, proprioceptive neuromuscular facilitation (PNF), or ballistic stretching (Cornelius & Rauschuber 1987, Etnyre & Abraham 1986a, Godges et al. 1989, Moore & Hutton 1980, Osternig et al. 1990, Sady et al. 1982, Sullivan et al. 1992, Wallin et al. 1985, Wiemann & Hahn 1997, Williford & Smith 1985), research has not demonstrated indisputably that one technique is better than another. Both PNF and static stretching are commonly advocated techniques.

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The static technique incorporates a slow stretch of a particular muscle or muscle group, held at the point of discomfort for a period of time ranging from 6 to 60 seconds (Bandy et al. 1997, Sady et al. 1982, Smith 1994, Webright et al. 1997). In our opinion, the majority of static stretching studies incorporate either a 15-, 30-, or 60-second duration. Bandy et al. (1997) reported that a 30-second static stretch is just as effective at improving hamstring flexibility as 60-seconds in an average age population of 26 years. However, Feland et al. (2001) found that 60-seconds was significantly more effective than 15- or 30-seconds in an elderly population (average age 85 years). The static stretch takes advantage of the inverse myotatic reflex, which promotes muscle relaxation and hence further stretch and ROM. The slow, controlled movement allows the stretch to be performed safely, with reduced risk of injury as compared to the other forms of stretching (Smith 1994).

PNF is a popular method of stretching that utilizes inhibition techniques (Kisner 1990); of these, contract-relax (CR), hold-relax (HR) and contract-relax antagonist-contract (CRAC) appear to be most commonly used. The optimal duration of isometric contractions used in the PNF technique is 3 to 6 seconds (Cornelius & Rauschuber 1987, Hortobàgyi et al. 1985).

No studies to date have reported specifically on acute changes in flexibility that can be obtained from a single 15-, 30-, or 60-second stretch to the hamstring muscle group just prior to activity in either a young or old population, while at least one study has reported immediate changes in PNF stretching.

Knowledge of the acute effects of one repetition of stretching is important to determine the efficacy of stretching and expected improvement in flexibility prior to activity. Remarkably, research documenting acute changes in flexibility within one stretching session is scarce. Magnusson (1998) reported that after a single 90-second static stretch, there was a 30% reduction in viscoelastic stress relaxation, which lasted about an hour. Halbertsma et al. (1996) observed the changes in hamstring flexibility with a single 10-min stretch. Halbertsma's study used 10 subjects (average age 25 years) and reported an average change of 8.9 degrees. Bohannon et al. (1984) reported that an 8-min loading stretch of the hamstrings (average age 23 years) produced an average increase of 3.7 degrees. Other studies have looked at flexibility changes secondary to stiffening or EMG effects from short-term stretching protocols (Etnyre & Abraham 1986b, Osternig et al. 1990), and in comparing cold or heat modalities (Henricson et al. 1984, Taylor et al. 1995).

Cornelius and Rauschuber (1987), however, appear to have the only report of acute changes in hamstring flexibility using a PNF technique. Their study looked at acute hip joint flexibility (average age population of 29.5 years) by measuring in between each of three trials. Even though the authors reported that PNF resulted in acute changes in hip joint flexibility, the primary result of their study showed that a contraction time of 10 seconds was not significantly better than a 6-second contraction when using PNF techniques.

The literature reports many benefits from stretching, including improved flexibility and injury prevention (Shellock & Prentice 1985, Smith 1994), athletic performance (Wilson et al. 1992, Shellock & Prentice, 1985), running economy (Godges et al. 1989), and possibly decreased symptoms of delayed onset muscle soreness (Buroker & Schwane 1989, Devries 1970). Most of these benefits refer to a young athletic population involved in sports performance, but they may also be applicable to the senior (defined as being age 55 or older) athlete, however, this has not been established in the literature.

Results of stretching studies in college-aged populations may not be generalizable to an elderly population due to age-related musculoskeletal and physiological changes. General age-associated changes that occur in skeletal muscle include decreased muscle mass with accompanying fiber atrophy and loss of fiber number (hypoplasia), motor unit remodeling and decreased axonal sprouting and number of motor units (Brooks, 1996). Skeletal muscle mass declines at an average rate of 4% per decade until the age of 50 years. The rate of loss after 50 years increases to 10% of the remaining skeletal muscle per decade (Fielding, 1995).

A particular physiologic change that occurs with age is atrophy of muscle cell size and number (Fielding 1995, Timiras 1994). It has also been noted that the muscle tissue may become yellow due to deposition of lipofuscin pigment and increased fat cells, or grey due to increased amounts of connective (fibrous) tissue (Timiras 1994). The collagen tends to lose its elasticity with age, as well as does capillary blood supply, which results in a reduced capacity for healing (Kisner 1990). It is theorized that in the matrix composition of tendons and ligaments, the collagen and water concentration may decline with age as the labile reducible collagen cross-links decrease, and that the more stable and non-reducible cross-links increase (Buckwalter et al 1993).

Since age-related musculoskeletal changes may alter the outcome of stretching protocols, the purpose of this study was to observe the acute changes in flexibility that result from one-stretch in the hamstring muscle group using either a static or CRPNF technique. The study involved seniors aged 55 years or older. This age group has been chosen since the majority of hamstring flexibility studies have utilized a younger population, typically in the range of 20–30 years of age.

Method

Subjects

Ninety-seven subjects (66 males, 31 females; mean age 65 years; range 55–79 years) participating in The Huntsman World Senior Games in St. George, Utah, USA, October 1999, volunteered for this study. Access to the subjects was granted through a health screening fair that is sponsored each year in conjunction with the games. Subjects attending the health fair were considered to be a sample of convenience, but representative of the senior athletic population. Subjects attending the health fair were randomly selected to participate in this stretching study. All participants were informed of the possible risks and signed an institutionally approved informed consent form. Subjects who recently completed an active warm-up or participated in sporting activities earlier that day, or who were experiencing signs or symptoms of delayed onset muscle soreness (DOMS), or soreness from previous injury, were not allowed to participate.

Experimental procedure

Measurement protocol

All subjects who qualified for the study were checked for knee extension ROM in a prone position to rule out knee joint contractures. Subjects were asked to perform four toe-touch stretches to decrease the effect of acute muscle-tendon lengthening attributed to viscoelastic behavior. Subjects were then placed in the supine position and a Penny and Giles goniometer was used to measure knee extension ROM. Unlike hand-held measurements, the Penny and Giles goniometer attaches to the lower extremity to be tested and remains there during the stretching. This decreases placement error.

Prior to data collection, a pilot study was performed by the researchers to establish intratester reliability in measuring hamstring flexibility using the goniometer and the placement bar. A test-retest design was used on 10 subjects with measurements taken 10 minutes apart by the same tester. An intraclass correlation coefficient (ICC) was used to determine reliability of terminal knee extension measurements (Shrout & Fleiss 1979). An ICC (3, 1) of 0.92 was considered sufficient to continue with the study.

Measurement of knee extension ROM was then made with the subject lying supine, with the opposite leg straight on the table, and the leg being measured held somewhere between 90 and 100 degrees of hip flexion in order to assure tightness of the hamstrings when the knee was extended. Subjects were also instructed to keep their low back flat on the table during the measurement procedure to limit further possible pelvic rotation during the measurement. Hip flexion position was maintained (same angle for pretest and posttest measures) by having the thigh stay in contact with a bar that crossed the table, while the lower leg was passively moved into the terminal position of knee extension. Since knee contractures were ruled out, lack of knee extension ROM in this position was considered to be a function of hamstring tightness, and thus a measure of hamstring flexibility.

For purposes of this study, the terminal position of knee extension was defined as the point at which the subject reported a complaint of 'mild discomfort' in the hamstring muscle group, resulting from the stretch. Once the terminal position was achieved, range of motion as measured by the goniometer was 'standardized to zero' to mark the baseline of hamstring flexibility prior to participation in either a static or PNF stretch. After being stretched, this process was repeated to determine the change in flexibility. Again, use of the bar assured that the hip was flexed to the same point in both measurements. A research assistant was used to zero the baseline measurement and to record the values displayed on the monitor so the researcher performing the stretching was blind to the results.

Treatment groups

All qualified subjects were randomly assigned to either the control group or one of two treatment protocols. Treatment one (40 subjects) consisted of stretching using a CRPNF technique. In this technique, the leg to be stretched was raised to the point of 'mild discomfort' in a straight-leg raising technique. Once the point of discomfort was reached, the subject was asked to perform a maximum voluntary contraction of the hip extensors for 6 seconds, the leg was then further raised to maintain 'mild discomfort' and the subject relaxed at that point for 10 seconds followed by another 6-second contraction and 10 more seconds of rest at the point of 'mild discomfort' for a total of 32 seconds of stretch time. This time period was chosen for two reasons; to create a total time of 32 seconds, which would most closely resemble the effective single static stretch time of 30 seconds as reported by Bandy et al. (1997), and to allow for 6-second PNF contractions which have also been previously mentioned as being the most effective.

Treatment two (38 subjects) consisted of stretching using a static stretch technique. With this technique, the leg was raised passively by the researcher to the point of mild discomfort and maintained for 32 seconds (to equal the total stretch time of the CRPNF group) with the subject constantly monitored and informed to relax the muscle being stretched as much as possible.

Subjects in the control group (19 subjects) were measured for hamstring flexibility and then remeasured after 32 seconds of rest. The time of 32 seconds was used because it equaled the amount of stretching time in the treatment groups.

Analysis

The control, CRPNF, and static groups were each measured twice, at pretest (directly before stretching) and posttest (directly after stretching), thus each subject served as his or her own control. Of interest was whether one or both of the interventions influenced flexibility. The Shapiro-Wilk test was used to test whether the change in flexibility scores from pretest to posttest was normally distributed. The hypothesis of normality was rejected for the control group ($P = 0.0013$), the CRPNF group ($P = 0.0077$), and the static group ($P = 0.0018$). Hence, the Wilcoxon signed-ranks test was used to test whether the medians, rather than the means, were equal in the two-paired samples. In addition, to compare pretest to posttest scores between intervention groups, rank analysis of covariance was used, with tests of pair-wise comparisons based on the Mantel-Haenszel mean score statistic (Koch et al. 1982, 1990).

Results

Wilcoxon signed-ranks tests show that the median difference in scores between pretest and posttest was significantly different than zero in each of the control, CRPNF, and static groups (Table 1). Pair-wise comparisons using rank analysis of variance revealed that the difference from pretest to posttest significantly differed between the control group and the CRPNF group ($P = 0.0001$) and the control group and the static group ($P = 0.0001$). However, no difference in flexibility gains between the CRPNF and static treatment groups were observed ($P = 0.1461$). These results remained unchanged after adjusting for age and gender, with corresponding P values 0.0001, 0.0001, and 0.0831, respectively.

Differences in flexibility scores from pretest to posttest were further assessed between CRPNF and static groups according to gender and age

Table 1 Differences in flexibility scores from pretest to posttest according to specific intervention categories

Intervention	Number	Median Difference	Variance	*P* value*
Control	19	1	0.474	0.0002
CRPNF	40	5	9.115	0.0001
Static	38	4	5.954	0.0001
Overall	97	3	8.729	0.0001

*Based on the Wilcoxon signed-ranks test.

Table 2 Difference in flexibility scores before and after CRPNF and static interventions according to gender or age (<65 and 65+)

Gender/Age group intervention	Number	Median Difference	Variance	*P* value*
Men				
CRPNF	28	6	8.683	
Static	25	4	3.393	0.0264
Women				
CRPNF	12	3.5	9.697	
Static	13	5	9.859	0.4650
Less than 65 years of age				
CRPNF	12	7.5	8.750	
Static	18	4	4.458	0.0225
65 years and older				
CRPNF	28	3.5	8.173	
Static	20	4	7.589	0.8152

*Based on Cochran-Mantel Haenzel Statistic derived using rank analysis of variance.

(Table 2). Median differences between these groups were significant for men, but not for women and for those aged less than 65, but not for those aged 65+. Hence, differences in scores between CRPNF versus static were more pronounced in men than women and among participants in the younger age group compared to the older age group.

Discussion

While many studies with elderly populations have incorporated general flexibility measurements, very few studies have looked directly at the effect of specific stretching protocols. The results of this study show that age appears to be a factor influencing acute flexibility gains in that CRPNF appears to be more effective in the younger age group (55–64 years), and that there is not a significant difference in acute flexibility gains between CRPNF or static stretching in senior athletes age 65 years or older. However, there was a significant difference between CRPNF and static stretching techniques in those aged 55 to 64 years, with CRPNF stretching producing significantly greater gains in acute (short term) hamstring flexibility than the static stretch.

Why PNF stretching is more effective in the younger age group is of great interest. The basis for PNF stretching is theorized to be through neural inhibition of the muscle group being stretched. The proposed neural inhibition reduces reflex activity, which then promotes greater relaxation and decreased resistance to stretch, and hence greater range of movement (Hutton 1993). However, Magnusson et al. (1996) noted that paradoxically, some studies have shown PNF techniques to be associated with greater electromyographic activity in the muscle being stretched when compared to a static stretch. Still, other research has found PNF techniques to promote greater relaxation (Crone & Nielsen 1989, Etnyre & Abraham 1986b).

The difference in PNF effectiveness between age groups may be associated with age-related musculoskeletal and physiologic changes. With increasing age, the soft-tissue matrices tend to lose elasticity and strength (Buckwalter et al.

1993). Also, 'there is a tendency for myofibrils to degenerate and be replaced by lipofuscin or connective tissue. Therefore, there is an increase in collagen of the skeletal muscle of older persons' (Spence 1989). The amount of type II fibres declines with age, and is correlated to the effects of inactivity and decreased axonal sprouting and motor neuron death, as well as reinnervation by adjacent Type I fibers (Brooks & Faulkner 1994). Type II fibres are fast twitch fibres that significantly contribute to force production in muscle. Studies have shown a marked decrease in H-reflex and M-wave amplitude with age. A study by Vandervoort and Hayes (1989) showed that the H-reflex in the soleus muscle of a group of women (mean age 81.7 years) was 43% that of a younger group of women with a mean age of 25.7 years. It is possible that the neurophysiologic changes associated with aging may hamper the PNF effect of decreasing or limiting motor neuron pool excitability. This possibility remains to be substantiated.

Research has shown that stiffness originating from muscles and inert tissue structures increases with age (Lung et al. 1996). Research has also documented a systematic decline in both active and passive range of motion of lower limb joints with age, with women generally maintaining a greater amount of joint mobility than men (James & Parker 1989). The evidence that women maintain joint mobility better than men in the aging process may help explain why the results of this study show that the effects of PNF had a greater effect in men than women. First, the women may have had greater initial flexibility to begin with so the change in men following intervention may have been greater. Second, men, particularly male athletes, may tend to retain greater amounts of type II muscle fiber, thereby retaining a greater amount of neural association, and the neurophysiologic effects of PNF stretching may have had a greater amount of reciprocal relaxation.

Of particular interest, was the amount of change in flexibility after one repetition of stretching. Even with one repetition of stretching, changes in flexibility appear to have been made, and the results of the study verify that both stretching methods led to greater knee extension ROM than not stretching. Still, there is a question as to how long these increases persisted.

It has been reported that the static stretch appears to be more desirable technique for compliance if comfort and limited training time are major factors (Moore & Hutton, 1980). Research also indicates that older muscles are more susceptible to contraction-induced injury, especially when the muscle is lengthened during the contraction (Medeiros et al. 1977). This could be interpreted as a possible contraindication to CRPNF stretching, especially in the elderly. However, in the study by Medeiros et al. (1977), repeated exposures to protocols of lengthening contractions resulted in a training effect that decreased the susceptibility of the muscle to strain from the lengthening contraction. These results were based on a subject base of 30 men with an average age of 26 years. Whether or not these results can be ascribed to the elderly population is unknown. Since the subjects participating in this study were perhaps more active than the general elderly population, the CRPNF method of stretching was considered safe to implement.

One other issue regarding PNF stretching still exists. The CRPNF technique has been theorized to alter stretch perception (Magnusson et al. 1996). Wiemann and Hahn (1997) observed the effect of static and ballistic stretching on ROM, end-ROM torque of hip joint flexion, resting tension of the hamstrings, and stretch-induced electromyographic activity of the hamstrings. The researchers suggest that the increased ROM after short term stretching exercises is a result of an increased tolerance to stretching strain rather than a decrease in resting tension. As previously mentioned, Magnusson (1998) reported that the 30% viscoelastic stress relaxation effects lasted approximately one hour. Magnusson went on to explain that inflexible and older subjects have increased muscle stiffness and a lower stretch tolerance than younger subjects. However, the younger age group was reported to be 15–21 years and the 'older' age group was 26–32 years. Further studies are needed to see if this theory of stretch tolerance is applicable to the elderly population (>50 years).

The amount of flexibility and ROM in joints and muscles affect one's ability to perform activities of daily living and avoid injury

(Gladwin, 1996). An elderly person's ability to perform various activities of daily living impacts quality of life and level of independence (Cunningham et al. 1993). The loss of postural stability predisposes the elderly to accidental falls and potential injury. The loss in stability may be the leading cause of falls in the elderly, but a combination of the decline in strength, balance and flexibility may also be related (Gehlsen & Whaley, 1990). Overall there is a lack of longitudinal data showing whether or not gains in overall fitness and flexibility translate to improved functional status or independence (Morey et al. 1989).

Summary

This study helps us understand how effective one repetition of stretching can be in improving flexibility of the hamstring muscle group prior to activity in an active elderly population. Whether this improved flexibility increases performance or decreases risk of injury is unknown. It also remains unknown how long these increases in flexibility persisted. While there was not a statistically significant difference between the CRPNF and static stretch treatments in those age 65 and older, both were effective at improving acute flexibility in the senior athletes tested, and the CRPNF had a greater effect in men than women. Overall CRPNF stretching appears to be more effective than static stretching at producing acute flexibility gains in the hamstrings muscle group in senior athletes age 55 to 64 years.

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